



U.S. Department
of Transportation
Federal Aviation
Administration

Advisory Circular

Subject: TURBINE ENGINE VIBRATION
SURVEY

Date: 2/14/97

AC No. 33.83

Initiated by: ANE-110

Change:

1. PURPOSE. This advisory circular (AC) provides guidance and acceptable methods, but not the only methods, that may be used to demonstrate compliance with the vibration survey requirements of part 33 of the Federal Aviation Regulations (FAR). This AC will be incorporated into AC 33.2, Aircraft Engine Type Certification Handbook at a later date.

2. RELATED FAR SECTION. Part 33, sections 33.63, 33.83, and 33.97.

3. BACKGROUND. The subject of vibration tests/surveys was identified as one where differences existed between the Joint Aviation Requirements - Engines (JAR-E) and the part 33 of the FAR. A study group composed of representatives of the Federal Aviation Administration (FAA), the Joint Aviation Authorities (JAA), Transport Canada and industry worked to produce a set of improved and harmonized vibration requirements that was subsequently incorporated into part 33 of the FAR. This AC is intended to provide guidance in implementing these new harmonized requirements during certification.

4. DEFINITIONS. The following are defined for the purpose of this AC.

a. Physical rotational speed (N_r). The raw uncorrected rotational speed of a rotor system measured in revolutions per minute (rpm).

b. Corrected rotational speed (N_c). The rotational speed of a rotor system corrected by normalizing the compressor inlet conditions to a standard condition of air at 59 degrees Fahrenheit (15 degrees Celsius). The correction values are empirically determined and are applied by the formula:

exponent

$$N_c = N_r / (T_{\text{inlet}} / 519)^{0.5}$$

where T_{inlet} is the compressor inlet temperature in degrees Rankine and the exponent is determined empirically but has a typical value of 0.5.

c. Resonance. A condition that results when the exciting force frequency coincides with one of the component's natural frequencies. A unique vibratory mode exists for each resonant response.

d. Endurance limit. The maximum value of alternating stresses, in combination with the appropriate steady-state stresses, that will not result in material fatigue failure.

e. Flight envelope. All airborne and non-airborne conditions of operation, including start-up and shutdown, both on the ground and in flight and windmilling rotation in flight,

f. Flutter. Flutter in a system having blades or vanes is a self-excited vibration that occurs at one of the blade's natural frequencies and at the associated natural vibratory mode. It is independent of any external excitation source, but is dependent upon the aerodynamic conditions over the blade and upon the blades aeroelastic properties.

5. SELECTION OF COMPONENTS. Analyses should be conducted to identify the engine components whose vibration characteristics require verification by engine test or by other means shown to be equivalent or more appropriate. The selected components would normally include:

a. The most critical blades and vanes, from a vibration point of view, in the fan and each compressor and turbine;

b. All blade rows adjacent to variable incidence vanes;

c. All fan disks, and the most critical disk, from a vibration point of view, in each compressor and turbine;

d. All main rotor shaft systems (and gears when included in such systems);

e. Any other component specifically identified as requiring engine test to substantiate analysis and/or to supplement component tests.

6. TEST CONDITIONS. The following alterations to the test conditions may be necessary to adequately assess the engine's

vibratory characteristics:

a. Rig testing. Normally a full engine test is the preferred means to complete the survey. However, an applicant may elect to use rig tests for overcoming limitations associated with a full engine test, such as the amount of instrumentation or range of inlet conditions that can be tested. If rig tests are employed, the applicant should demonstrate that all pertinent interface conditions closely model actual engine operations.

b. Speed extensions. The full stress survey should be the goal, and the test program arranged accordingly to cover at least the ranges of conditions required under section 33.83(b). Where extensions to those ranges are considered necessary for the identification of the effects of the rising vibratory stress peak, as required under section 33.83(b), but if it proves physically impractical to achieve the appropriate extended test conditions, the effects of the rising vibratory stress peak should be adequately assessed by another means to be agreed with the FAA.

c. Instrumentation survivability. Where the engine operates at such high rotor speeds, and gas path temperatures that test instrumentation can only survive the environment for short periods of time, some form of analysis acceptable to the FAA would be expected to complete the substantiation.

7. ALTITUDE EFFECTS. Engine tests may be conducted by flight test, or in altitude facilities, or in other facilities such that the effects of flight and altitude are properly represented and can be evaluated. Suitable test equipment and instrumentation should be used for each situation. Any alterations made to the engine for the purpose of achieving test conditions should be evaluated to show that the alterations are acceptable.

8. FLUTTER. Testing required to demonstrate satisfactory vibratory clearance from flutter boundaries may be accomplished by compressor rig, or engine sea-level, or altitude test.

a. The hardware standard and the intake conditions and margins to account for engine deterioration should be taken into consideration. Further, the methods used to verify the absence of damaging levels of flutter throughout the declared flight envelope should include consideration of applicable combinations of the following:

(1) The ranges of physical and corrected rotational speeds for each rotor system;

(2) The simultaneous occurrence of maximum compressor inlet air total temperature and maximum corrected rotational speed (e.g., maximum relative velocity);

(3) The range of compressor operating lines within the flight envelope, and

(4) The most adverse of other compressor inlet air conditions encountered within the flight envelope (e.g., applicable combinations of total air pressure, density, temperature, and inlet distortion).

b. As flutter is a phenomenon which can be sensitive to small variations in those factors which could influence the response of the system, due consideration should be given to possible variations, between the nominal and extreme values of, for example, tip clearances, mechanical damping, operating lines, bleed flows, etc. Experience has also shown that there are differences in susceptibility to flutter from one blade set to another and that "tuned" blade sets might be more sensitive.

9. VARIATIONS IN MATERIAL PROPERTIES AND NATURAL FREQUENCIES.

Allowance should be made for the usual variations in material properties and natural frequencies of production components when interpreting test results or analytical predictions.

10. RESONANT DWELL. If any significant resonance is found within the operating conditions prescribed in section 33.83 of the FAR, then the relevant components should be subjected to sufficient cycles of vibration close to, or on, the resonance peak to demonstrate compliance with section 33.83(d) of the FAR. This resonant dwell testing would normally be incorporated into the incremental periods of part 33 section 33.87 of the FAR, Endurance test, as required by sections 33.87(b)(4), 33.87(c)(4), and 33.87(d)(5) of the FAR. Components subjected to resonant dwells must meet the requirements of part 33, section 33.93 of the FAR, Teardown inspection.

11. INSTRUMENTATION INCOMPATIBILITY. If the dimensions of the blades or vanes are incompatible with the necessary instrumentation, instrumented engine tests to substantiate the vibration characteristics of compressor blades, turbine blades, compressor vanes, and turbine vanes, may be waived in whole or in part, if the FAA is satisfied that the total hours of operation accumulated on test beds or in flight, under representative conditions, prior to certification is sufficient to demonstrate that vibration stress levels are acceptable.

12. INSTALLATION COMPATIBILITY. Section 33.83(f) of the FAR ensures vibratory compatibility between the engine and each intended installation configuration when the engine is installed and operated in accordance with the manufacturer's approved instructions. The engine manufacturer will be expected to provide sufficient information in the installation instructions required by section 33.5, to enable the aircraft manufacturer(s) to establish that the installation does not unacceptably affect the engine's vibration characteristics. In establishing vibratory compatibility between the engine and the installation, consideration should be given to the need to declare operating limitations and procedures. Where appropriate, at least the following features should be considered:

- a. Each propeller approved for use on the engine;
- b. Each thrust reverser approved for use on the engine;
- c. Installation influences on inlet and exhaust conditions;
- d. Mount stiffness;
- e. Rotor drive systems; and
- f. Accessory components.

13. INSPECTION REQUIREMENTS. The pre-certification activity necessary for determining which engine components require verification by engine test, and also for determining the proper location of engine test instrumentation, will typically include substantive tests and analyses for determining component (or system) natural frequencies, mode shapes, steady state mean stress, and vibratory stress distributions. These development activities will generate engineering data essential to supporting the certification test, and should be exempt from formal FAA approval of test plans and reports. Inspection of type design hardware in accordance with the requirements of section 21.33 of the FAR, should be limited to only those pertinent engine components and associated instrumentation that constitute the certification engine test.

/s/ James C. Jones
Acting Manager, Engine and Propeller Directorate
Aircraft Certification Service